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DEVELOPMENT AND APPLICATION OF A TASK TAXONOMY FOR TACTICAL FLYING.

Volume II.

By

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This technical report has been reviewed and is approved for publication.

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A taxonomy of tactical flying skills was developed as a user-oriented skill-task analysis system for practical application in solving TAC continuation training problems and for a behavioral data base for skill maintenance and reacquisition training research and development. Sixteen representative tactical air-to-air and air-to-surface maneuvers were analyzed and classified within the system with provision for later expansion. A classification system was developed to accommodate the complexities of tactical flying. A data system was organized with sufficient flexibility to objectively address many areas of tactical flying. The taxonomy system also included methodology for addressing on-going training problems and requirements.

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SUMMARY

This is Volume II of the three volume technical report which describes the development and application of a taxonomy of tactical flying tasks. Volume II specifies the rationale and methods used to generate a taxonomic structure for tactical flying tasks. It shows how surface task analysis data, generated using procedures detailed in Volume I, can be integrated into a taxonomic hierarchy and matrix. This integration process was accomplished by developing a system of procedures and rules which were then applied to quantify, classify, and incorporate the surface analysis data within the taxonomic matrix.

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PREFACE

This report represents a portion of the research program of Project 1123, United States Air Force Flying Training Division, Mr. James F. Smith, Project Scientist; Task 112302, Instructional Innovations in the United States Air Force Flying Training, Mr. Robert R. Woodruff, Task Scientist.

Credit for the initial development of this study as a contract effort belongs to Capt Jack Thorpe who is now with the Air Force Office of Scientific Research, Bolling AFB. His work in writing the statement of work and guiding the formative stages of the contract was fundamental to the success of the final product.

Dr. Edward E. Eddowes, Technical Advisor, Air Force Human Resources Laboratory, Flying Training Division, Williams Air Force Base, Arizona, provided much guidance and insight throughout this effort. His contributions were particularly valuable because of his close association with Mr. Meyer in producing a Behavioral taxonomy of undergraduate pilot training tasks and skills, a research effort upon which the present study was based.

The authors express appreciation to Lt Col Tom Rush, Chief of the 4444th OS, Luke Air Force Base, Arizona, and to Maj Kirk Ransom and Maj Dick Phillips, TAC/DOOS, for their cooperation and support in the contract effort.

An essential element for this study was obtaining interview data from aircrew personnel at the 334th and 336th OS, Seymour Johnson Air Force Base, North Carolina. The focal point for coordinating these interviews was Capt Larrie Harlan, to whom the authors are grateful.

Capt Bill Schnittger, Chief of the F-4 Instructional Systems Development Team, Luke Air Force Base, Arizona, acted as principal liaison between the Contractor/Contract Monitor and the Tactical Air Command personnel involved in this project. The authors appreciate his continuing cooperation and contributions throughout the study, without which the contract could not have been successfully completed.

Valuable information and suggestions for the project were contributed during various meetings with the Contractor by Maj J. D. Brown, Capt Dave Yates, Maj Al Lavoy, Maj Bill Mack, Capt Jim Icenhour, and Mr. Don Alford of the 4444th OS, Luke Air Force Base, Arizona, and by Lt Col Dick Lee, TAC/TAWC, Eglin Air Force Base, Florida.

INTRODUCTION

This is Volume II of a three volume technical report documenting the development and application of a behavioral taxonomy of tactical flying tasks and skills. Volume I described the process of generating surface task analysis rules and techniques for sixteen selected tactical flying tasks representing 59 percent of the basic fighter maneuvers in the tactical domain. The resulting surface analyses of these maneuvers became the data base from which the task taxonomy was derived. As was the case with Volume I, Volume II is divided into two sections. The first section describes the methods used in developing the data classification system. Rules and a rationale for a skill coding system, taxonomic hierarchy, and sorting matrix are elaborated. Then, procedures applying those classification components to produce a functional taxonomic data system are described.

The second section is designed for the data user. It presents a step-by-step manual of instructions to guide the practitioner in generating his own taxonomic system using rules and procedures elaborated in the first section. The application of Volume II procedures is dependent upon the user having available to him a useful data base of maneuver surface analyses generated according to procedures described in Volume I of this report. Thus, the second sections of both Volumes I and II of this study have been prepared to permit flying training personnel who have had no previous experience with task taxonomies to successfully operate or enlarge the taxonomic system. The taxonomic data system is intended as an analytical tool for assessing, analyzing and comparing task components within and among all maneuvers by the taxonomy system.

BACKGROUND

It is important to understand that the information contained in the task element sequences of the surface task analysis has provided the data base for the taxonomy of tactical flying skills. Thus, the full potential of the completed surface task analysis cannot be realized until specific information has been processed from each of the task elements: Cues (C), Mental Action (Me), and Motor Action (Mo).

During the research program to develop a Behavioral taxonomy of undergraduate pilot training tasks and skills by Meyer, Laveson, Weissman, and Eddowes (1974), specific classification rules were developed based on meaningful behavioral characteristics which could be systematically extracted from the surface analysis. These rules were modified and refined to better reflect the more dynamic tactical flying task requirements. The revised rules were validated by researchers in order to determine the internal consistency and the repeatability of the classified data resulting from their use. Once this validation was complete, it was possible to establish a hierarchy of rules and a matrix system for organizing taxonomic information.

CLASSIFICATION DEVELOPMENT

The approach to classification development was to try out the rules on selected tasks. All researchers participated in trial classifications. Results were compared and rules revised or adjusted in order to reveal the most useful behavioral characteristics and to remove any ambiguity regarding phraseology. The classification rules were thus refined through a number of iterations until the researchers found agreement among the results of their rules application. Next, new tasks were classified and internal agreement among researchers was checked. Agreement was checked throughout the classification period and an average agreement (not counting simple clerical errors) was found to exceed 90 percent. No fundamental errors were found in the rules during the classification of the remaining tasks.

The Taxonomic Coding System - A simple coding or shorthand system was needed to develop the behavioral elements in each established classification category. This development proceeded as a parallel effort to the refinement of the classification rules. A requirement for the system was that it should be meaningful in notation form and, therefore, easily understood by both project researchers and flying personnel who would later utilize the taxonomy. An alphanumeric system was adopted since it could be made to convey recognizable data in raw form. Past experience in taxonomic organization indicated that the recognition of the taxonomic code would assist researchers in using the data and also provide a way of checking for clerical errors.

With this data coding system, meaningful alpha designators could be related to specific elements or component areas and numbers could be used for the ranking and counting of data. As an example, each representative task has been given an alpha-numeric code. A list of these tasks is shown in Table 1.

All controlled range tasks have a CR designator and the task number followed by the letter a denoting an air-to-air task or a g denoting an air-to-ground task. (Tactical range flying tasks, for instance, would have a TR designator followed by a task number and the a or g notation.)

The following breakdown has been used to identify each important part within the surface analysis. Figure 1 shows that each individual element in a C-Me-Mo sequence has been given a respective 1-2-3 identifier in the black square near the top of each analysis sheet. Each full C-Me-Mo sequence has been given a consecutive alphabetical designator. Thus

Table 1. Representative Flying Task List

Air-to-Air	
CR-1a	Single Turn Conversion
CR-2a	Reattack
CR-3a	Reversal
CR-4a	Counter Reversal
CR-5a	Low Yo-Yo
CR-6a	Counter Low Yo-Yo
CR-7a	High Yo-Yo
CR-8a	Counter High Yo-Yo
CR-9a	Racetrack DART
Air-to-Ground	
CR-1g	High Dive Bomb
CR-2g	High Dive Toss
CR-3g	Pop-Up Low Level Delivery
CR-4g	Low Angle Strafe
CR-5g	Nuclear Low Angle Drogue Delivery
CR-6g	Low Angle Dive Bomb
CR-7g	30° Rockets

any task, task sequence, or element within any sequence can be annotated during the classification procedure. This simple code also allowed all tasks, sequences and elements to be referenced and cross referenced for access within the taxonomy.

The Behavioral Element Categories shown in Table 2 are directly related to the classification rules of the taxonomy. These categories convey the data derived from the information within the task elements of the surface analysis. Table 2 shows the alpha-numeric coding system for the classifications. The codes were chosen to show a direct relationship to the language contained within the behavioral categories. For example, <u>Ai</u> means aileron and <u>V</u> always means visual. This was kept consistent throughout the representative task list, the surface task analysis, and classification rules and instructions.

SITUATION: Defender in a defensive turn, sees high energy attacker and performs a Reversal maneuver to a tracking gun shot.

TASK NO. CR-3a TASK Reversal/Controlled Range AIRCRAFT F-4E

TASK GOAL Defender to become the attacker DATE Sept., 1977

EL. SEQ.	1 CUES	2 MENTAL ACTION	3 MOTOR ACTION
A.	ESTABLISHED LEVEL DEFENSIVE TURN/ATTACKER IN SIGHT		
	Visual-Pitch att: constant Bank att: constant Threat (aircraft) Aural-Normal aircraft sound, communication - WSO *(calls threat's position) Control-Aileron & stabilator pressure Motion-Constant positive G	Determines attacker's range & recognizes overtake Sustains defensive turn	Checks six, maintains required aileron & stabilator control
B.	CONTINUES TURN Visual-Pitch att: constant Bank att: constant Threat Aural-Normal aircraft sound, *communication - WSO Control-Aileron & stabilator pressure Motion-Constant positive G	Determines overshoot developing & need to increase turn rate of force overshoot	Checks six, coordinates aileron & rudder pressure, moves stabilator
C.	CONTINUES TURN Visual-Pitch att: increasing Bank att: constant Threat Aural-Chg. in aircraft sound, *communication - WSO Control-Increased aileron, rudder & stabilator pressure Motion-Increasing positive G	Determines overshoot continuing & need to increase turn rate & reduce power	Checks six, coordinates aileron & rudder pressure, moves stabilator, reduces throttle
D.	CONTINUES TURN AS OVERSHOOT DEVELOPS/ATTACKER SLIDES THRU 6 O'CLOCK POSITION		
	Visual-Pitch att: increasing Bank att: rolling Threat Aural-Chg. in aircraft sound *communication - WSO Control-Aileron, rudder & stabilator pressure; throttle function Motion-Increasing positive G, deceleration	Determines attacker definitely overshooting Sustains turn	Checks six, maintains required aileron & stabilator control

Figure 1. Surface task analysis format example.

Table 2. Behavioral Element Categories and Coding System

1 CUES	2 MENTAL ACTION	3 MOTOR ACTION
Kind	**Information Process**	**Continuity**
Visual.......V	Multi-Cue..........MC (Determines)	Establish Attitude......A
Aural........A	Iterative...........I (Sustains)	
Control......C	Specific-Cue........SC (Discerns)	
Motion.......M	Multi-Cue/Iter......MC(I) (Determines/Sustains)	Establish Rate of Attitude Change........R
	Memory Recall/Iter..MR(I) (Anticipates/Sustains)	
	Specific-Cue/Iter...SC(I) (Discerns/Sustains)	
Quantity	**Decision Process**	**Motor Output**
1 Cue.........1-C	Simple Processing.....SP	Aileron.........Ai
2 Cues........2-C		Stabilator......St
3 Cues........3-C	Complex Processing.....CP	Rudder..........Ru
4 Cues........4-C		Throttle........Th
		Trim............Tr
		Communication...Cm
		Checks..........Ck
		Discrete........Ds
Input Index	**Input/Output Index**	**Output Index**
Total possible Cues versus the total number of actual Cues / I Value	Sum of the input index X the sum of the output index / I/O Value	Value..........V-1
		Value..........V-2
		Value..........V-3
		Value..........V-4
		Value..........V-5

RULES FOR CLASSIFICATION

The taxonomy was developed in order to identify the behavioral elements contained within the C-Me-Mo sequences of the surface task analyses. These behavioral elements have been extracted from the surface analyses through the application of specific classification rules which provide the structure required to identify and separate them into meaningful groups. Each rule and rationale is presented in the following discussion.

Rules for Cues Classification

Rule 1. Cues Kind - There are from one to four kinds of major cues available to the pilot in each element sequence.

Visual Cues - Visual cues may be found outside the cockpit, such as the horizon or target, or inside the cockpit as in the case of the flight instruments.

Aural Cues - Aural cues (such as engine sound, and environmental sounds like slipstream over canopy) were considered only when there was a change from a previous state; thus, a normal environmental sound was not considered a cue for this classification.

Control Cues - Control cues in the analyses were the pressures transmitted to the pilot's hands and feet as a result of displacement of aircraft controls. These pressures were primarily tactual and were an important source of feedback to the pilot. Neutral control pressures were presumed to occur when the pilot was not moving the controls or holding a control out of its trimmed position. Neutral control pressures were also not considered cues for this classification.

Motion Cues - Motion Cues provided the final cue considered in the cue classification process. A motion cue was said to be present when a condition other than normal (+1 G) flight was perceived. This cue included rolling, pitching, buffeting, and accelerating or decelerating in any axis.

Each major cue kind is listed using the following alpha coding:

V - Visual
A - Aural
C - Control
M - Motion

Rule 2. Cues Quantity - This rule enumerated the major cues identified in each task sequence. The combinations of major cues are listed as follows:

1-C	2-C	3-C	4-C
V	VA	VAC	VACM
	VC	VAM	
	VM	VCM	

Rule 3. Cues Input Index - This index expressed a percentage relationship between the number of cues available under each major cue heading a particular task sequence versus the number of possible cues. This total was determined by analyzing the sixteen representative air-to-air and air-to-ground tasks that made up the taxonomic data base. A total of 20 inside and outside cues were determined and are shown in Table 3.

The input index was calculated by counting the number of cues under each major cues heading, dividing this number by 20 (total number of possible cues), and then multiplying by 100 to achieve the percentage.

Example: $\frac{6 \text{ (number of cues in this sequence)}}{20 \text{ (maximum possible number of cues)}} \times 100 = 30$

Rules For Mental Action Classification

The mental action classification scheme and the action verbs contained in the surface analysis sequences were subjected to extensive study. The concept of categorizing mental action by a description of the information processing that is taking place was formulated after extensive review of many behavioral classification systems and trial applications to the taxonomy format. All previous taxonomic schemes have relied heavily on theory and conceptualization in classifying mental activity. Definitions for the categories usually suggested for describing mental activity have overlapped considerably. The approach during this research was to utilize the observable inputs to and outputs from mental activity. This mental activity is referred to as Information Processing. By identifying what information is processed, rather than how it is processed, the difficulties of describing or defending learning theories were circumvented, and a focus on the classification of behavior was maintained.

Table 3. Possible Cues and Respective Cue Categories

VISUAL -	Pitch attitude: climb	2
	Bank attitude: rolling	
	Target	5
	Range landmarks	
	Leading aircraft	
	Flight Instruments: airspeed, altimeter	
	(Instruments were considered singularly)	
AURAL -	Change in aircraft sound	3
	Communication - WSO	
	Weapons tone	
CONTROL -	Increased aileron pressure	5
	Increased rudder pressure	
	Increased stabilator pressure	
	Trim switch	
	Mic. button function	
MOTION -	Positive G	5
	Pitching up	
	Rolling	
	Vibration	
	Buffeting	
Total number possible inside and outside cues		20

Rule 1. Information Processing - The action verbs contained in the information processing rule are the same as defined in Volume I of this research. A review of each definition can be found in Appendix A of this report. The selection of the appropriate mental action category can be accomplished by comparing the action verb(s) used in the surface task analysis and utilizing the proper descriptive codes shown below:

Determines.......Multi-Cue Processing - MC
Anticipates......Memory Recall Processing - MR
Sustains.........Iterative Processing - I
Discerns.........Specific Cue Processing - SC

In those sequences which reflect a mental time sharing activity, or more than one action verb in the category, the following combinations have been identified:

Determines/Sustains - Multi-Cue Processing/
Iterative - MC(I)

Anticipates/Sustains - Memory Recall Processing/
Iterative - MR(I)

Discerns/Sustains - Specific Cue Processing/
Iterative - SC(I)

Rule 2. Decision Processing - This category requires a judgment on the part of the classifier. To determine whether a mental action involves simple or complex mental processing, the following definition should be applied:

A. Simple Processing - SP - Decisions which were based solely on the presentation of specific cues information or the recall of specific learned facts or procedures which require no estimation or extrapolation to plan, verify, or perform subsequent motor action(s).

B. Complex Processing - CP - Decisions which were based on the estimation or interpretation of cues information and the interpretative recall of facts or procedures to plan, verify, or perform subsequent motor action(s).

Rule 3. Input/Output Index - The approach presented in this rule was to concentrate on the observable inputs to and outputs from mental activity rather than to become involved in that theoretical domain of describing the mental activity itself. Thus, combining the inputs (cues) and outputs (motor actions) numerically was a logical final step in categorizing mental actions.

The input/output index was determined by using the product of the input index and the output index as follows: input index x output index = Input/Output Index.

Rules for Motor Action Classification

Rule 1. Continuity - This rule provided the taxonomy with information about the connective quality between each sequence within a flying task. Thus, this rule relates the previous and following motor actions as they occurred in a maneuver and shows the dynamic qualities of the effector outputs.

This rule determined whether the result of the flight control motor actions established a stable aircraft attitude or produced a continued rate of attitude change. The code

A is used to note the establishment of an attitude. The code R is used to note the establishment of a rate of attitude change in the flying task.

Rule 2. Control Output - This rule identified the specific motor activities of the pilot. As most of the motor activity is associated with controlling the aircraft's position with respect to a three dimensional environment, it was natural to define the specific motor action in terms of the flight controls used. Hence, control output categories of stabilator, aileron, rudder, throttle and trim were used. In addition, it was also necessary to account for several other types of motor activities such as communication and checking within the target area where the act of looking required unusual body and head movement or a great deal of physical strength as a result of high G loads on the pilot. Discrete activation of system control switches and knobs was also accommodated under a general heading. The following outputs and abbreviations were used:

Aileron	- Ai	Trim	- Tr
Stabilator	- St	Communicates	- Cm
Rudder	- Ru	Checks	- Ck
Throttle	- Th	Discrete	- Ds

Rule 3. Output Index - A final category identified the amount of motor activity taking place within each task sequence. An output index system was devised which addressed the number of motor activities occurring in each motor action element and whether these activities were performed successively, one at a time, or simultaneously in a coordinated manner. The output index ranking was derived as follows:

Value 1 - One output
Value 2 - Two or more successively performed outputs
Value 3 - Two coordinated outputs
Value 4 - More than two coordinated outputs
Value 5 - Coordinated and successively performed outputs

CLASSIFICATION HIERARCHY DEVELOPMENT

A classification tree or hierarchy was developed using the nine rules which formed the behavioral categories in the taxonomy classification system. Considerable experience, gained in this area during earlier research of a Behavioral taxonomy of undergraduate pilot training (UPT) tasks and skills, was applied to the present effort.

It was determined during the earlier research that emphasis on different rules produced a different hierarchical structure; however, the results of the classification would remain unchanged. The development then was a matter of producing a hierarchy which would produce: 1. a logical sifting of skill information for simplified data application and retrieval, and 2. as much visibility of information as possible which would be important to researchers who would use the taxonomy.

During the earlier taxonomic research, it was difficult to foresee all the areas to which taxonomic data might be applied. With this in mind, it was determined that a hierarchy structure should be designed to provide maximum flexibility in manipulation and access of information.

In order to achieve a logical sifting of information within the taxonomy, a distribution frequency of sorting variables was established using data from the nine classification rules. This was done noting the number of variables resulting from data generated by these rules. Table 4 shows the distribution of the number of sorting variables or choices for each classification rule and their respective behavioral categories.

Experience has shown that the practical sorting of information into a useful matrix would be greatly simplified if the simple choices were made first and followed logically to the most complex combinations. It can be seen that the Decision Processing behavior of the mental action category is first with Simple or Complex Processing as the only two choices resulting from that rule. It was chosen over the Continuity behavior, also with two choices, because it was determined that sorting of major mental complexity would be the most meaningful in terms of training information. It should be noted at this point, that a taxonomic hierarchy could be established with the rules placed in any relationship to one another.

Table 4. Classification Hierarchy Listing

Classification Rule	Distribution	Category
I. Simple or Complex Decision Processing	2 Choices	Mental Action
II. Continuity - Establish Attitude/Rate of Attitude Change	2 Choices	Motor Action
III. Quantity (1-C, 2-C, 3-C, 4-C)	4 Choices	Cues
IV. Kind (V, VA, VC, VM, VAC, VAM, VCM, VACM)	4 Choices	Cues
V. Output Index (V-1, V-2, V-3, V-4, V-5)	5 Choices	Motor Action
VI. Information Processing (MC, MC-I, MR-I, I, SC, SC-I)	6 Choices	Mental Action
VII. Input Index (20 thru 85 in increments of 5)	14 Choices	Cues
VIII. Motor Output (Control/Control System Combinations)	26 Choices (approx.)	Motor Action
IX. Input/Output Index (40 thru 400 in increments of 10)	36 Choices (approx.)	Mental Action

Figure 2 shows the final classification hierarchy. The hierarchy has already taken into consideration the physical problems of sorting within the actual classification matrix. This is shown by the positioning of the rules within the intended sub-block and sorting slot levels.

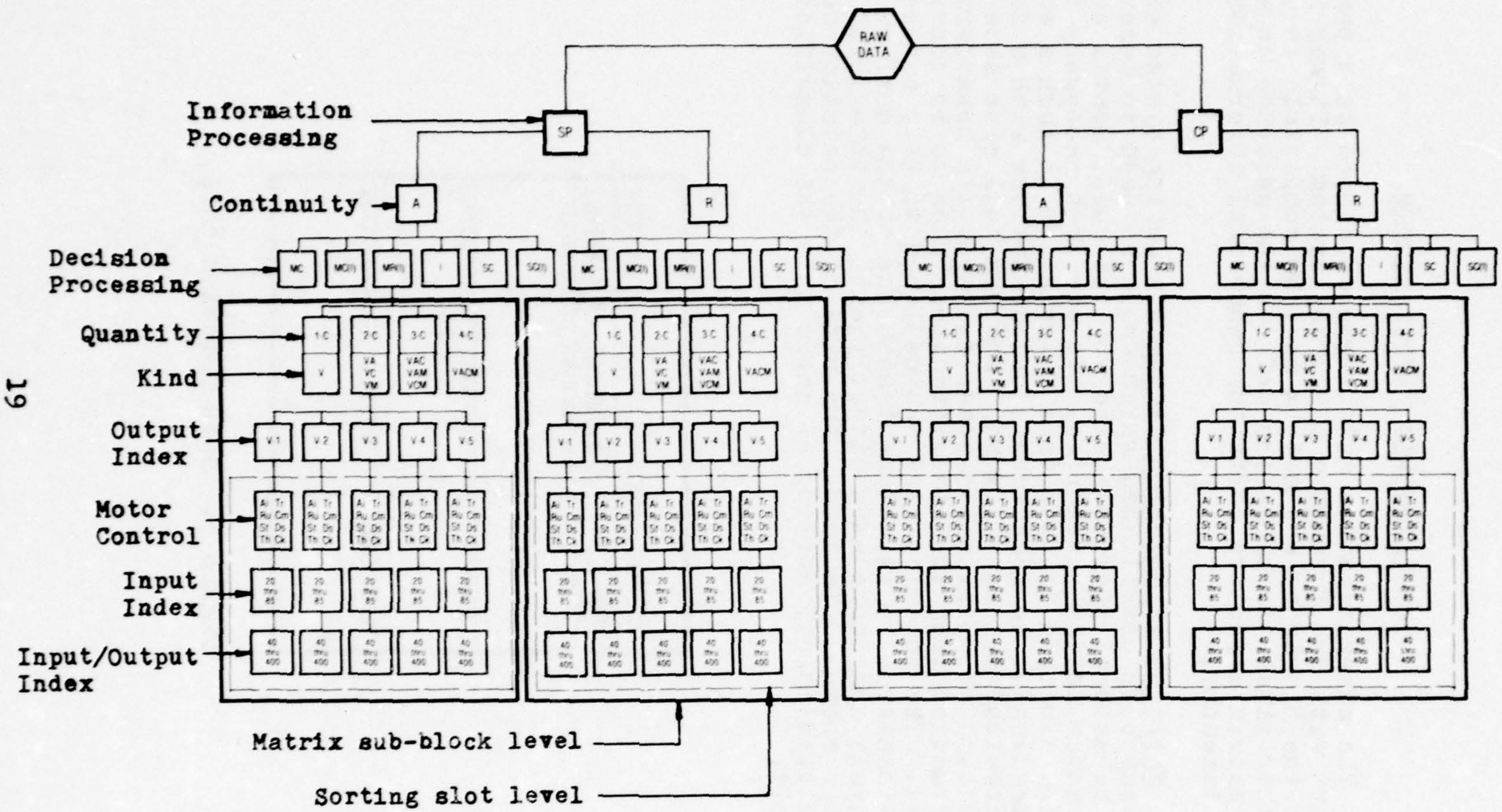


Figure 2. Classification hierarchy.

THE TAXONOMIC MATRIX SYSTEM

The classification matrix was developed as a parallel effort with the taxonomic hierarchy system. It was found that the hierarchy and matrix must be compatible to one another since the hierarchy defines the sequence in which the matrix structure sorts the behavioral information of the taxonomy.

Matrix Data Notation System - A coding system had already been established which would be used to describe the behavioral characteristics of the cues, mental action, and motor action categories. It was then necessary to devise a method to note this information in such a way to be meaningful to researchers and compatible with a functional information matrix. Figure 3 shows a full size data notation card which provides space for specific behavioral information from the classification rules to be conveniently noted. The notation card was designed to bear a resemblance, in miniature, to the element sequence of the surface task analysis and correlates directly with the behavioral categories shown in Table 2. The size of the notation card permitted manual sorting of cards into the classification matrix.

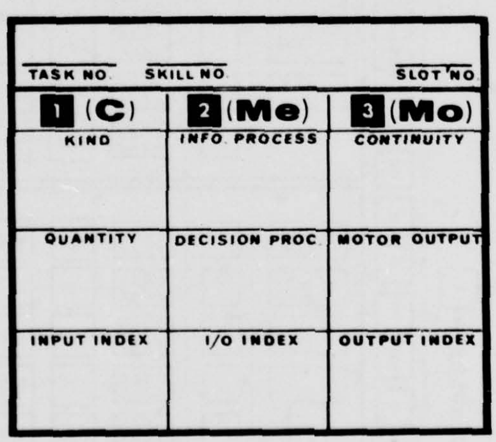


Figure 3. Data notation card.

The Classification Matrix - During the development of a Behavioral taxonomy of undergraduate pilot training tasks and skills, researchers determined that a matrix of pigeon holes, or slots, was a satisfactory method of sorting specific behavioral information. A sorting slot matrix provided for a hands-on approach to working with the classified data.

Since the classification data were recorded on 2½ by 3 inch notation cards, consideration was given to the physical size of the final matrix board. The development of the taxonomic hierarchy also impacted the layout of the matrix. The final configuration in Figure 4 shows that the Decision Processing (simple or complex) category provided the basic division for the matrix followed by the Continuity category which divided flying behavior into establishing an aircraft attitude (A) or rate of attitude change (R). The Information Processing category, which includes Multi-Cue or (MC), Multi-Cue (Iterative) or MC(I), Memory Recall (Iterative) or MR(I), Iterative or (I), Specific Cue or (SP), and Specific Cue (Iterative) or SP(I) behavioral descriptions, further organized the data into 24 groups called sub-blocks. In the example sub-block shown at the bottom of Figure 4, the vertical axis contains the Cues Quantity category with four choices while the horizontal axis contains the Motor Action/Output Index category with five choices. Thus, each matrix sub-block contains 20 sorting slots, giving the entire classification matrix a capacity of 480 numbered slots.

The two dimensional layout of the matrix encompassed six of the nine classification categories and established a 7 by 8 foot working matrix board. The three remaining classification categories (Motor Output Index, Input Index, and Input/Output Index) were accommodated within the matrix sub-blocks. A three dimensional or cubic structure was thus devised which allowed the sorting of notation card data variables for the remaining categories.

A small rod was projected out from each of the numbered sorting slot faces so that cards containing identical data could be clipped together into groups and the final sorting completed. Figure 5 shows the three dimensional cubic structure discussed above. This figure also shows the step-by-step development and working relationship between the components of the taxonomy.

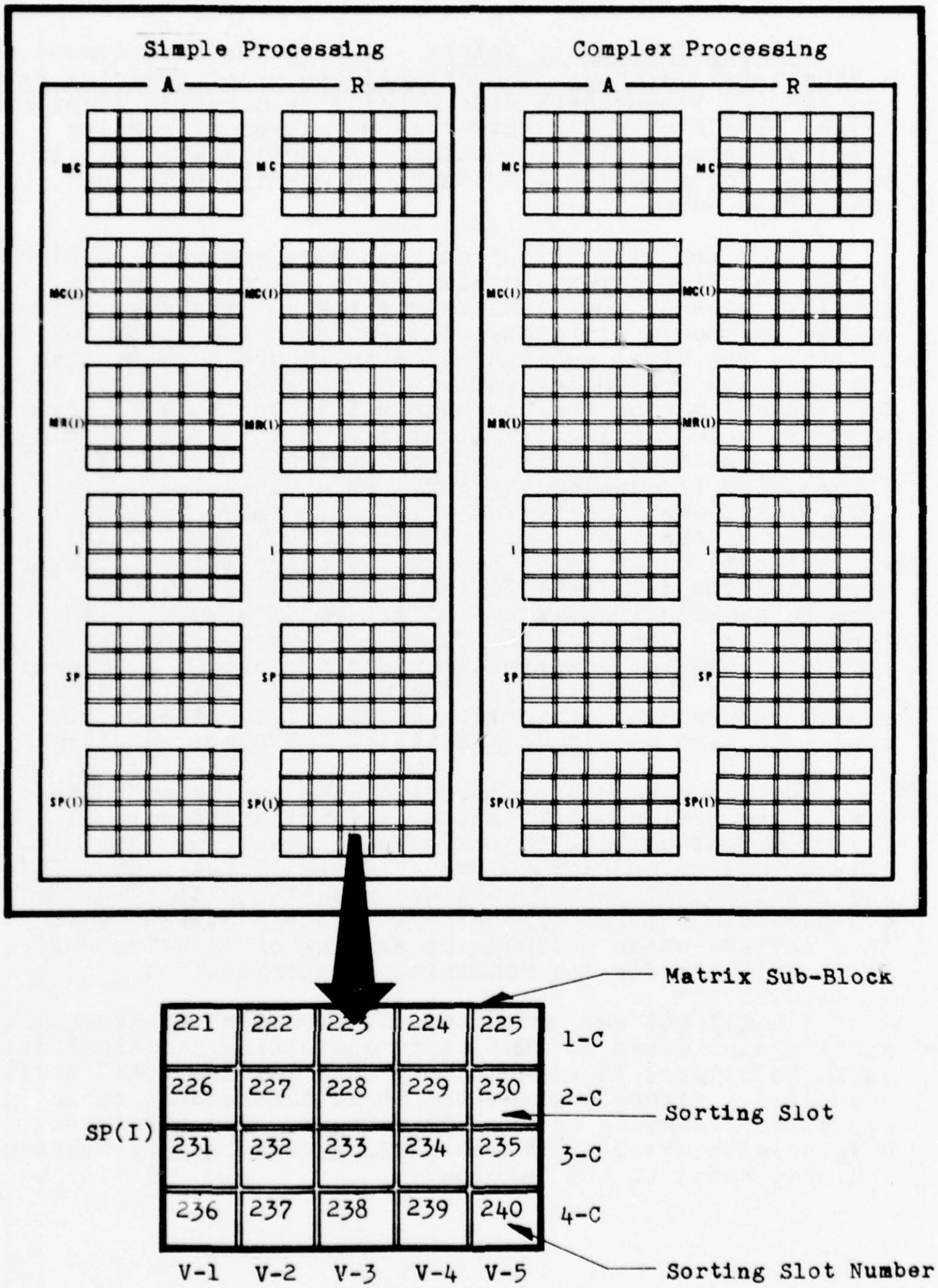


Figure 4. Classification matrix layout.

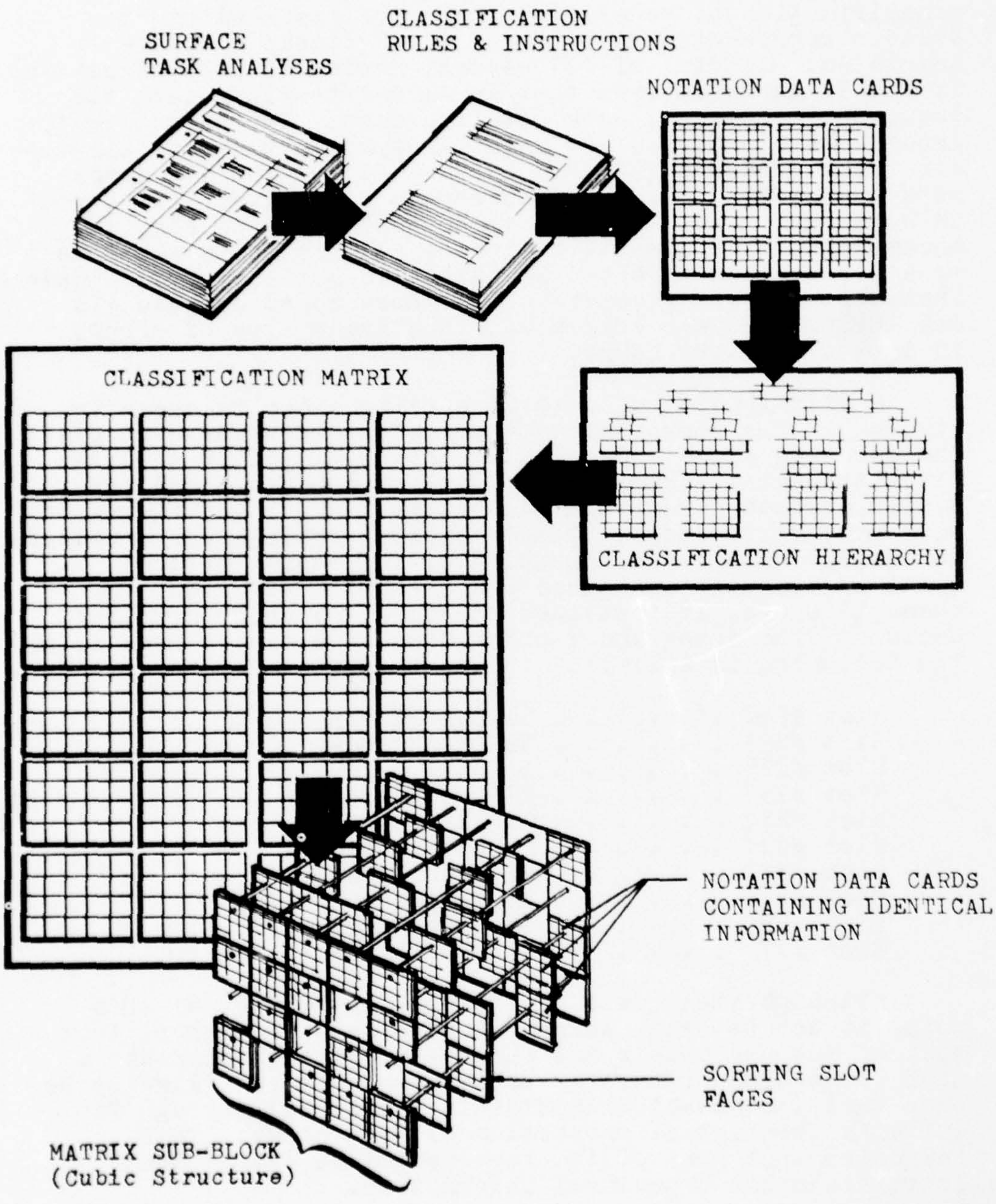


Figure 5. Matrix development procedure.

Data Sorting Within the Classification Matrix - With all the working components of the taxonomy in place, the classification of behavioral characteristics within the sixteen representative tactical flying tasks could be completed. A total of 475 element sequences were classified. It should be remembered that in classification, each task sequence yielded one data notation card. The seven air-to-ground tasks produced 284 data cards while the nine air-to-air tasks produced 191 data cards. All of the 475 cards were processed through the taxonomic structure. The hands-on sorting operation proved to be both fast and easy to accomplish. The classification of all task data was done by a person inexperienced in taxonomic methodology. Simple instructions were given (such as those found on page 41) and the process was completed, relatively free of error, in less than eight hours.

A distribution of data in sorting slots is shown in Figure 6. The number of data cards is shown for each slot. The darkened slots indicated slots which contain no data. Since the matrix contained a total of 480 slots and the number of data cards totaled 475, it was not surprising to note many empty slots. The clustering of data was considered consistent with the homogeneity of the tasks involved. A total of 61 slots contained one or more data cards. Of these 61 slots, 16 contained one card - 9 under Simple Decision Processing and 7 under Complex Decision Processing. The following is a list of the most populated sorting slots.

Slot #280 . . . . 64 Data Cards
Slot #277 . . . . 39 Data Cards
Slot #275 . . . . 34 Data Cards
Slot #257 . . . . 27 Data Cards
Slot #252 . . . . 22 Data Cards
Slot #337 . . . . 22 Data Cards
Slot #332 . . . . 20 Data Cards
Slot #260 . . . . 16 Data Cards
Slot #287 . . . . 15 Data Cards
Slot #17 . . . . 15 Data Cards

Although these data are general in nature, at this point it can be seen, using Figure 6 as a reference, that most of the air-to-air and air-to-ground tasks contain a high proportion of complex processing. It can likewise be seen that the sub-block containing slots 261 through 280 contains the highest proportion of data cards. This indicates that many of the representative flying tasks contain similar behavioral information.

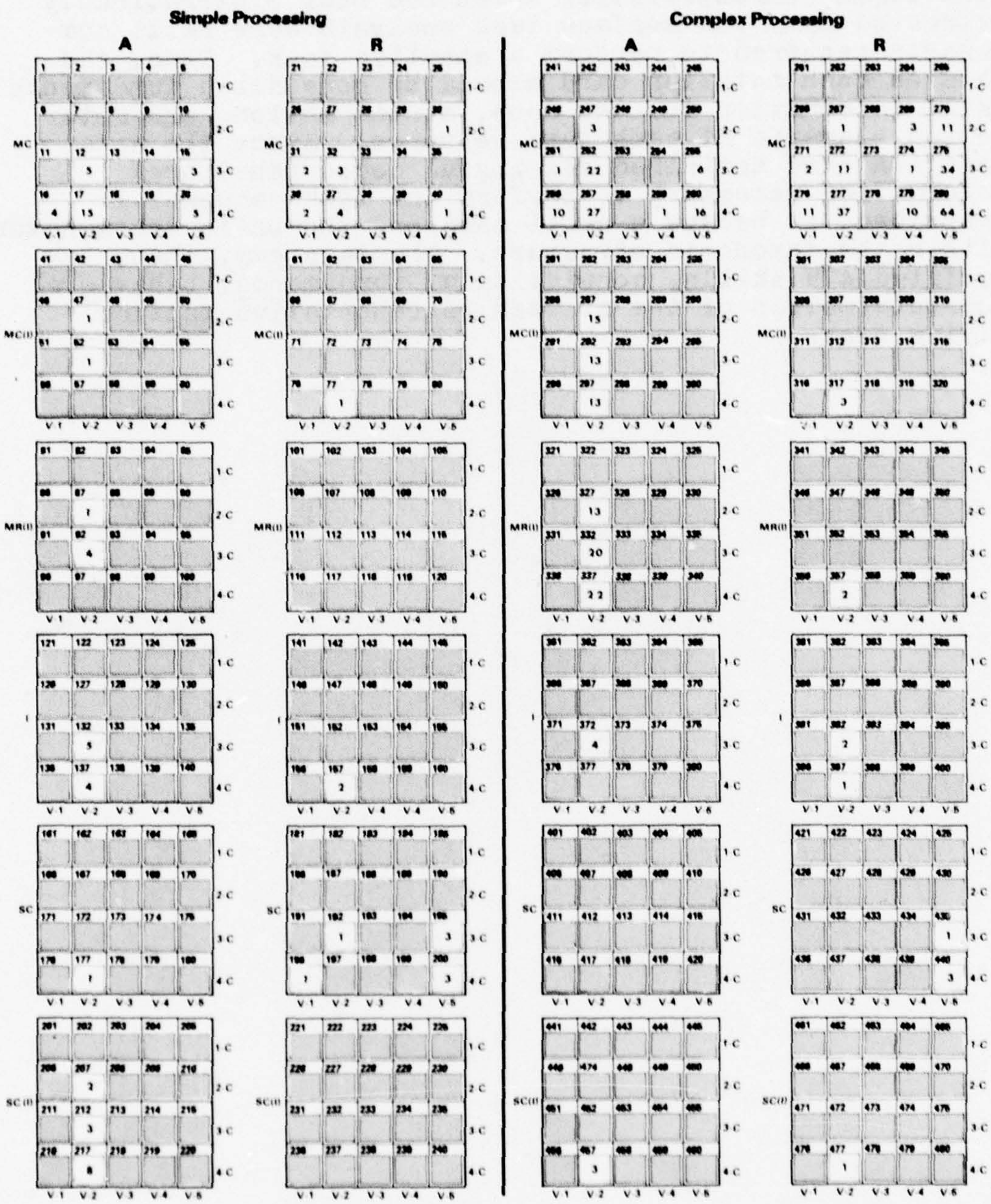


Figure 6. Taxonomic matrix system.

Notation Card Data as Skill Information - Previous experience with taxonomic classification indicated that behavioral characteristics which had been systematically extracted from the surface task analysis were skill components required to perform a specific task. Thus, the data on each notation card should be considered fundamental skill information for the cues, mental action, and motor action elements of each task sequence. Since the data notation card contained meaningful coded behavioral information necessary to perform the task sequence it described, it became a skill card and the basic denominator within the taxonomic structure. The taxonomy, then, has isolated 475 skills, consisting of fundamental behavioral characteristics of the sixteen representative tactical flying tasks.

THE TAXONOMIC DATA SYSTEM

A taxonomy is essentially a categorization and sorting of component parts according to specific rules and instructions. Thus far, a practical hands-on approach had been taken to the construction of this taxonomy. This approach ensured a practical understanding of all aspects of the taxonomic structure. The hands-on approach also provided user oriented rules descriptions and instructions. It, likewise, allowed researchers to cross-check skill card information derived from the surface analysis. Because of the easily understood data coding system, information could also be checked as it entered the classification matrix to eliminate functional or clerical errors.

Data System Development - It was determined that in order to utilize data contained within the taxonomy, a comprehensive data system would have to be devised. Again, previous experience had shown that the best application of the taxonomy was accomplished through the proper sorting, organization, and comparison of its data. It was thus necessary to allow data to be retrieved, used, and returned to the taxonomy as easily as possible. It was also not considered practical to continue to have a 7 by 8 foot classification matrix board as part of the final system.

The classification had already been simplified as shown in Figure 6. This simplified matrix, however, could not show the data within the depth of each sorting slot. For this reason, a sorting slot list was established. Table 5 shows an example of this listing for sorting slots in matrix sub-blocks 21 through 40. Each skill or task sequence which the classification rules have sorted into each slot has been recorded in the code established for the surface task analysis. Identical skill sequences are shown bounded by a slash (/) on either side of the group. Skill sequences which have some similar qualities, but were not classified as identical, are shown at the end and separated by commas. A complete sorting slot list for all tasks can be found in Appendix B.

It was determined that a complete cross-indexing system would be required in order for the data system to function properly and that each of the taxonomic components would need to be referenced, one to another. For this reason a complete skill card file was established which contained not only the skill data but also the task, task sequence, and sorting slot to which it had been classified. Figure 7 shows a typical card with the indexing information across the top.

Table 5. Sample Sorting Slot List

Slots 21 thru 40			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	21-29 None	35	None
30	CR-1g(Q)	36	CR-1g(HH), CR-7g(II)
31	/CR-1g(FF), CR-4g(FF)/	37	CR-1a(EE), CR-3a(H),
32	CR-4g(L), CR-6g(FF),		CR-4a(Q), CR-2g(HH)
	CR-7g(L)	38	None
33	None	39	None
34	None	40	CR-2a(O)

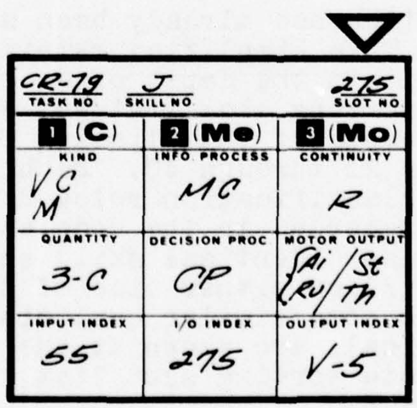


Figure 7. Typical skill card.

It was also necessary to cross reference each task sequence within the surface task analysis with the classification matrix and all the other components of the taxonomy. Figure 8 shows how this was done. It should be noted that the data contained on the skill card for each task sequence are found in a block above the motor action entry of the sequence.

TASK NO. CR-7g TASK 30° Rockets Delivery/Controlled Range AIRCRAFT F-4E

TASK GOAL Perform Rocket Delivery DATE Sept., 1977

EL. SEQ.	1 CUES	2 MENTAL ACTION	3 MOTOR ACTION
J.	CONTINUES ROLL OUT Visual-Pitch att: decreasing Bank att: roll Target Range landmarks Leading aircraft Aural-Normal aircraft sound Control-Increased aileron & rudder, decreased stabilator pressure Motion-Decreasing positive G, pitching down, rolling	Determines satisfactory roll rate & need to reduce power	CR-7g TASK NO · J SKILL NO · 275 SLOT NO 1 (C) KIND: VC M · QUANTITY: 3-C · INPUT INDEX: 55 2 (Me) INFO PROCESS: MC · DECISION PROC: CP · I/O INDEX: 275 3 (Mo) CONTINUITY: R · MOTOR OUTPUT: Ai Ru / St Th · OUTPUT INDEX: V-5 Maintains coordinated aileron & rudder with stabilator movement, adjusts throttle

Figure 8. Surface analysis example with skill data and sorting slot numbers.

The taxonomy classification has now become a data system which can be utilized effectively to sort, organize, and compare flying skill information.

<u>A Breakdown and Explanation of the Taxonomic Data System</u> - Figure 9 shows the entire taxonomic data system and how all the parts are integrated and cross-indexed to one another. Tasks and task sequences described in the surface analysis can be analyzed in relation to skills by indexing the skill card file to the task numbering list. The data contained on each skill card can be found related to the classification matrix and sorting hierarchy. The following is an explanation of each part of the taxonomic data system.

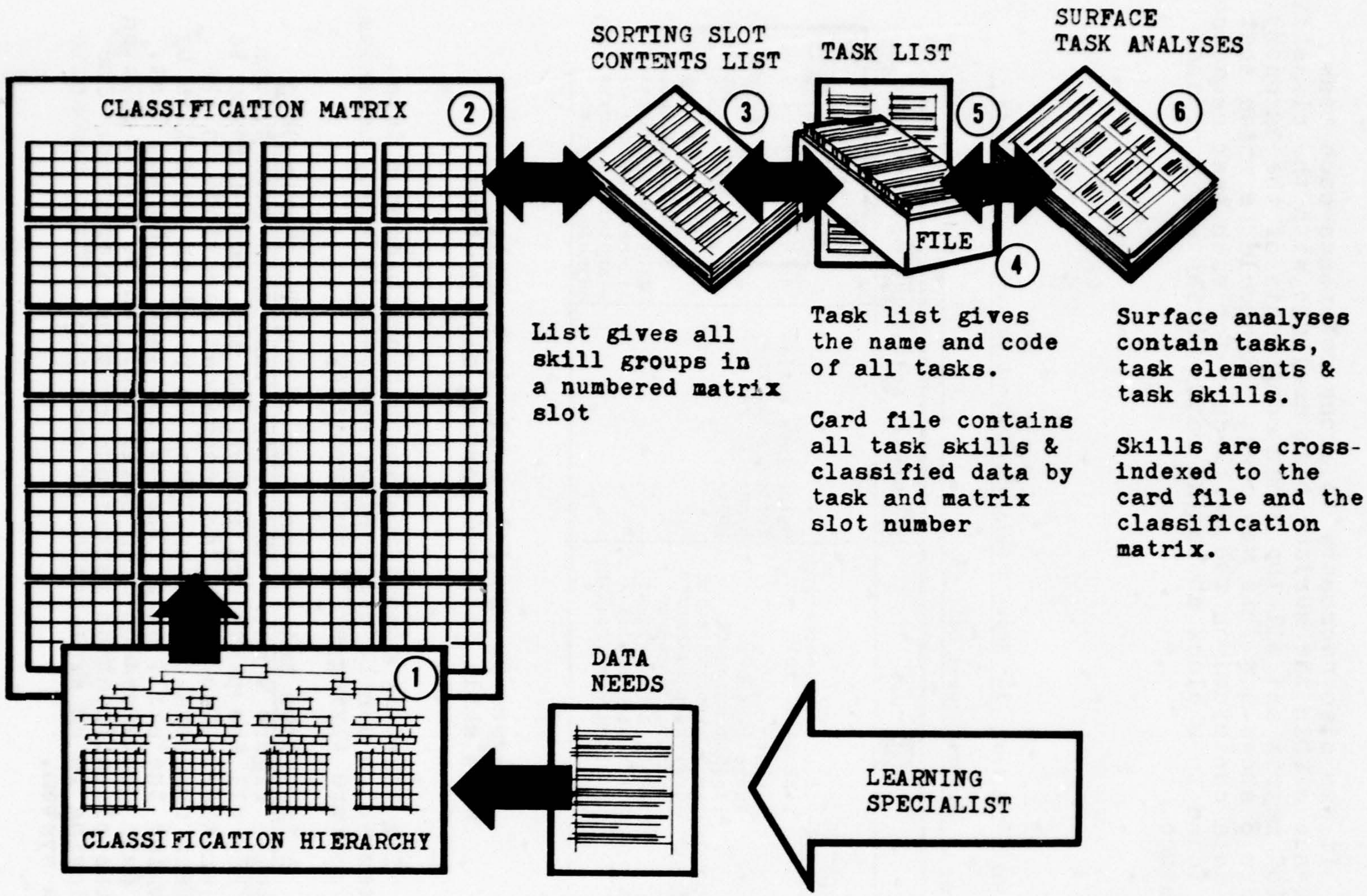


Figure 9. Taxonomic data system.

1. Classification Hierarchy - This was the basic organizational structure used in categorizing all tasks and skills within the taxonomy. It was directly related to the nine rules used to classify all tasks in the surface analysis. The hierarchy shows at what specific levels data generated by each of the nine rules can be found.

2. Classification Matrix - The classification matrix was the primary device used in sorting all flying skills into basic skill groups. Consequently, it also became the focal point of the taxonomy as a useful tool. Note that the classification hierarchy provided the basic organization of the information as it entered the matrix. The matrix, composed of 24 sub-blocks, allowed the final sorting of skills into basic skill groups with the order shown in the classification hierarchy. The original research matrix was a 7 by 8 foot board which allowed a hands-on method of developing a useful system. This large board was refined into a two dimensional matrix. Each matrix sub-block showing the cues/kind (one through four on the vertical axis) and the motor action/output index ranking (one through five on the horizontal axis) was consistent with the classification hierarchy. Each slot in the matrix was numbered and showed the number of skills it contained.

3. Sorting Slot Content List - This list shows the tasks and skills in coded form and established the identical skill groups contained in each slot in a matrix sub-block.

4. Task List - This list translated the task code into the task name and is related directly to the surface analysis tasks.

5. Card File - A skill card file was established to cross reference all skill information in the taxonomy data system. These skill cards are filed by task according to the order shown on the task list.

6. Surface Task Analysis - The surface analysis provided the task information upon which the taxonomy was built. Each task was made up of task sequences with the cues, mental action, and motor action (C-Me-Mo) elements forming the substance of each sequence. Since the C-Me-Mo elements are the building blocks for identifying the skills of each task, reference to this information can be most important to researchers. For this reason, the skill information found on each file card is also found as a cross reference in each C-Me-Mo sequence in the surface analysis.

The finalizing of the taxonomic data system concluded the architecture of classifying the behavioral characteristics of tactical flying tasks. The following section of Volume II consists of a users manual, which describes in a step-by-step manner the classification and sorting functions required for a taxonomy of tactical flying tasks and skills. It should be noted that Volume III of this study deals with the specific use and application of taxonomic data to real-world flying training problems.

USERS MANUAL FOR THE CLASSIFICATION AND TAXONOMIC ORGANIZATION OF TACTICAL FLYING TASKS AND SKILLS

The surface task analysis of the sixteen representative tactical flying tasks served as the data base for the step-by-step classification instructions. It is these analyses which provided the behavioral information in the form of described cues, mental actions, and motor actions for taxonomic classification. The nine specific rules for classification have already been discussed. These rules will now be broken down into simple instructions which tell how the surface analysis data are to be utilized for the classification procedures.

Another important part of the classification is the data notation card already discussed in the first section. The behavioral information in each flying task sequence was entered in a simple code on this card form. Figure 10 shows a typical analysis sequence. Notice that the data notation card follows the same general format of the analysis. Each notation card contains a cues, a mental action, and a motor action category with three blocks below each category. The completion of all nine blocks constitutes the classification of one task sequence.

Before beginning, the task number and skill number should be completed as shown. Now follow the instructions for classification.

1 Instructions for Cues Classification - Using the example surface analysis sequence in Figure 10, enter the appropriate codes on the data notation card in the following blocks:

— Kind - List each major cue in the task sequence by its abbreviation. V - Visual, A - Aural, C - Control, and M - Motion are considered major cues. <u>Do not list any of these cues if they are described as NORMAL or NEUTRAL</u>.

SITUATION Aircraft established on downwind at 7000' AGL, 300-350 knots, weapons select switches set and confirmed with WSO, second aircraft in flight, first pass, new event.

TASK NO. CR-7g **TASK** 30° Rockets Delivery/Controlled Range **AIRCRAFT** F-4E

TASK GOAL Perform Rocket Delivery **DATE** Sept., 1977

EL. SEQ.	1 CUES	2 MENTAL ACTION	3 MOTOR ACTION
J.	CONTINUES ROLL OUT Visual-Pitch att: decreasing Bank att: roll Target Range landmarks Leading aircraft Aural-Normal aircraft sound Control-Increased aileron & rudder, decreased stabilator pressure Motion-Decreasing positive G, pitching down, rolling	Determines satisfactory roll rate & need to reduce power	Maintains coordinated aileron & rudder with stabilator movement, adjusts throttle

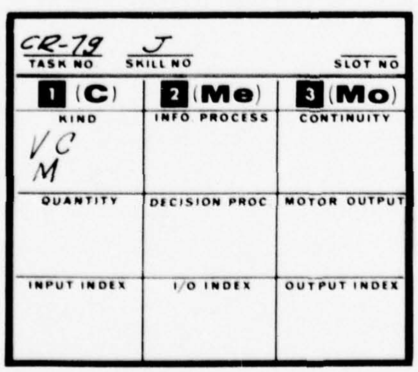


Figure 10. Surface analysis and data notation card relationship showing a cues kind classification example.

Quantity - Count the number of major cues. Record the number of cues in the quantity block, either 1-C, 2-C, 3-C, or 4-C.

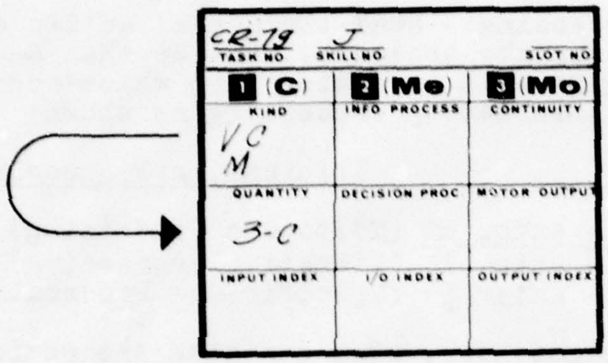


Figure 11. Cues quantity example.

Input Index - To arrive at the Input Index value, use the following procedure:

A. Count the number of individual cues under all four major cues categories. For example, under Visual cues count pitch attitude, bank attitude, target, range landmarks, and leading aircraft. Aural is normal so is not counted. Increased aileron and rudder are counted along with decreased stabilator pressure. All three motion cues are counted for a total of 11 individual cues.

B. Divide the number of individual cues by 20 and multiply the result by 100. Round to the nearest whole number and enter the sum in the Input Index block.

Example: $\dfrac{\text{11 (number of individual cues)}}{\text{20 (maximum possible cues)}} \times 100 = 55$

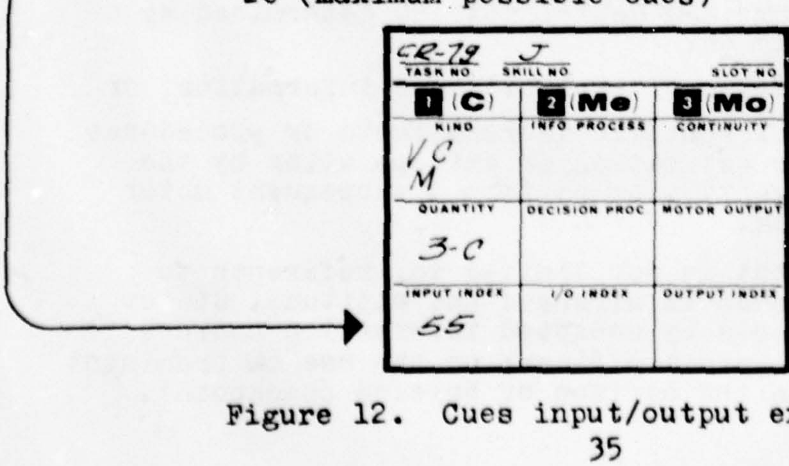


Figure 12. Cues input/output example.

2 Instructions for Mental Action Classifications- Using the example surface analysis sequence, enter the appropriate codes on the data notation card in the following blocks:

Information Processing - Read the mental action entry (or entries) in the surface analysis. Notice that each behavioral entry begins with an action verb which corresponds to a form of Information Processing as shown:

Action Verbs		Information Processing
1. Determines	- enter MC	(Multi-Cue Processing)
2. Sustains	- enter I	(Iterative Processing)
3. Discerns	- enter SC	(Specific Cue Processing)

A mental action category which contains two action verbs denotes a time shared mental activity. In these cases, the top mental action is written first, and the second action follows it written in parenthesis. For example, a mental activity containing the action verbs Anticipates and Sustains would be written MR(I). The following combinations which may be found in the analyses are shown below:

4. Determines/Sustains - Multi Cue/ Iterative Processing...MC(I)
5. Anticipates/Sustains - Memory Recall/ Iterative Processing...MR(I)
6. Discerns/Sustains - Specific Cue/ Iterative Processing...SC(I)

Decision Processing - Read the entry in the mental action and determine if the action is Simple Processing (SP) or Complex Processing (CP) by the following procedure:

Simple Processing (SP) mental actions determined by decisions based solely on:

1. The presentation of explicit cues information, or

2. The recall of specific learned facts or procedures which require no estimation or extrapolation by the pilot to plan, verify, or perform a subsequent motor action or actions.

This includes, but is not limited to, reference to instrument readouts such as airspeed and altitude; direct inflight verbal commands by accepted information sources such as the weapons systems officer; or the use of prominent outside references as the horizon or briefed checkpoint.

TASK NO. CR-7g TASK 30° Rockets Delivery/Controlled Range AIRCRAFT F-4E

TASK GOAL Perform Rocket Delivery DATE Sept., 1977

EL. SEQ.	1 CUES	2 MENTAL ACTION	3 MOTOR ACTION
J.	CONTINUES ROLL OUT Visual-Pitch att: decreasing Bank att: roll Target Range landmarks Leading aircraft Aural-Normal aircraft sound Control-Increased aileron & rudder, decreased stabilator pressure Motion-Decreasing positive G, pitching down, rolling	Determines satisfactory roll rate & need to reduce power	Maintains coordinated aileron & rudder with stabilator movement, adjusts throttle

CR-79 TASK NO	J SKILL NO	SLOT NO
1 (C)	2 (Me)	3 (Mo)
KIND VC M	INFO PROCESS MC	CONTINUITY
QUANTITY 3-C	DECISION PROC	MOTOR OUTPUT
INPUT INDEX 55	I/O INDEX	OUTPUT INDEX

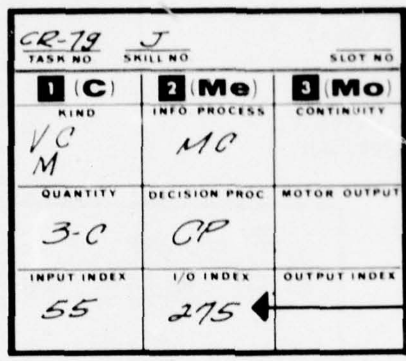
Figure 13. Surface analysis and data notation card relationship showing an information processing example.

Complex Processing (CP) - Mental actions based on the estimation or extrapolation of cues information and the interpretative recall of learned facts and procedures to plan, verify, or perform a subsequent motor action or actions. This includes, but is not limited to, estimating the roll in position during a weapons delivery, when a pull-up should begin during a low yo-yo, or concluding the proper pipper movement schedule to a target.

CR-79 TASK NO	J SKILL NO	SLOT NO
1 (C)	2 (Me)	3 (Mo)
KIND VC M	INFO PROCESS MC	CONTINUITY
QUANTITY 3-C	DECISION PROC CP	MOTOR OUTPUT
INPUT INDEX 55	I/O INDEX	OUTPUT INDEX

Figure 14. Mental action decision processing example.

Input/Output Index - This value is determined by multiplying the value of the input index and the value of the output index. In actual practice, the Output Index would require completion before this value could be completed. (In this case the Output Index is 5.) The Input/Output Index is 55 x 5 = 275.



CR-79 TASK NO	J SKILL NO	SLOT NO
1 (C)	2 (Me)	3 (Mo)
KIND VC M	INFO PROCESS MC	CONTINUITY
QUANTITY 3-C	DECISION PROC CP	MOTOR OUTPUT
INPUT INDEX 55	I/O INDEX 275	OUTPUT INDEX

Figure 15. Mental action input/output example.

3 Instructions for Motor Action Classification - Using the example surface analysis, enter the appropriate codes on the data notation card for the following blocks:

Continuity - Read the entry in the Motor Action column of this task sequence, then drop down and read the cues in the next sequence of the analysis. Determine whether the cues and action establish a specific aircraft attitude or rate of attitude change.

List either the A code for Establishes Attitude or the R code for Establishes Rate of Attitude Change in this block according to the following guidelines:

1. Establish Attitude (A) - The condition in which the motor action produces stable (non-moving) pitch and bank cues.

Example: The stabilized pitch and bank attitude in an established turn.

2. Establish Rate of Attitude Change (R) - The condition in which either a pitch or bank cue, or pitch and bank cues are moving continuously.

Example: The continuous pitch and bank movements present when going into a turn.

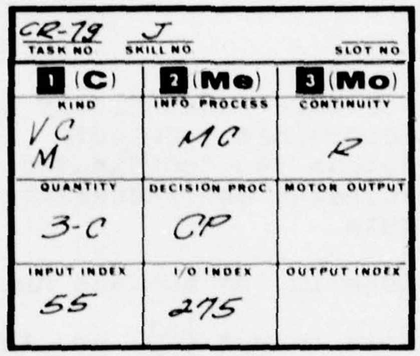


Figure 16. Motor action continuity example.

Control Outputs - Read the Motor Action entry in the task sequence and list all the control outputs by writing the abbreviation of the controls affected on the data notation card using the following codes:

Aileron	- Ai	Trim	- Tr
Stabilator	- St	Communicates	- Cm
Rudder	- Ru	Checks	- Ck
Throttle	- Th	Discrete	- Ds

Example: Coordinates aileron and rudder, maintains stabilator pressure, moves throttle. These motor actions would be noted in the block as follows:

Coordinated Outputs	Ai Ru	St Th	Successively performed Outputs

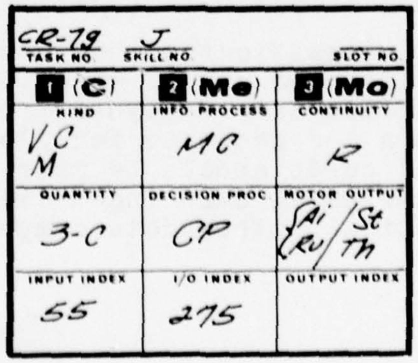


Figure 17. Motor action motor output example.

Output Index - Count the number of control outputs listed in the output block, then qualify and rank them as follows:

Value 1 - One output
Value 2 - Two or more successively performed outputs
Value 3 - Two coordinated outputs
Value 4 - More than two coordinated outputs
Value 5 - Coordinated and successively performed outputs

The motor actions in the surface analysis example showed one coordinated output $\left\{\begin{matrix}\text{Ai}\\ \text{Ru}\end{matrix}\right.$ and two successively performed outputs $\left|\begin{matrix}\text{St}\\ \text{Th}\end{matrix}\right.$. This combination has a value of 5.

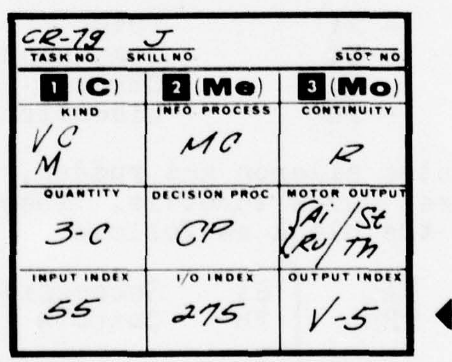


Figure 18. Motor action output index example.

When the data classification has been completed, a data notation (skill) card should exist for each task sequence of the surface task analyses performed. After rechecking each card and sequence for clerical errors, a second set of skill cards should be made for each task. These cards form the skill card index file which allows the cross referencing of all other data components within the taxonomy.

Sorting Data - After the behavioral information specified by the nine classification rules has been taken from each sequence of the surface task analyses and recorded on skill cards, it must be sorted. It should be noted again that the final objective of the taxonomic process is to isolate and identify those flying characteristics which are identical across all sixteen representative tactical tasks. The classification hierarchy and matrix now come into use to complete the taxonomy. The academic aspects of the classification hierarchy and matrix have already been explained. The following steps are required to sort the classified data.

Step 1. - The sorting is done according to the classification. The data notation or skill cards for each task are sorted by determining whether they are Simple Processing - SP, or Complex Processing - CP. This is under the Decision Processing block in the center of the card. Sort out the cards into two groups on a table.

Step 2. - The next sorting consisted of separating each Simple and Complex Processing group by Continuity in the upper right block of the card. The two choices are A for establish aircraft attitude or R for establish rate of attitude change.

At the completion of this sorting step there will be four data groups on the table - A and R groups under Simple Processing and A and R groups under Complex Processing.

Step 3. - The next data breakdown consisted of separating the cards according to Information Processing which is the top center block of the card. Information Processing consists of six choices: MC, MC(I), MR(I), I, SC, and SC(I). Before starting this separation, care should be taken to identify and remember the basic SP and CP groupings since they form the basic breakdown on the matrix board.

Now separate each of the four groups according to the six Information Processing choices. Upon completion, the data cards will have been sorted into 24 groups of cards.

Step 4. - At this point in the sorting process, the Classification Matrix Board is brought into use. Figure 19 shows the layout of the matrix board containing 480 sorting slots and 24 sub-blocks. Notice that the sub-blocks are divided into two basic headings: Simple Processing, SP, and Complex Processing, CP.

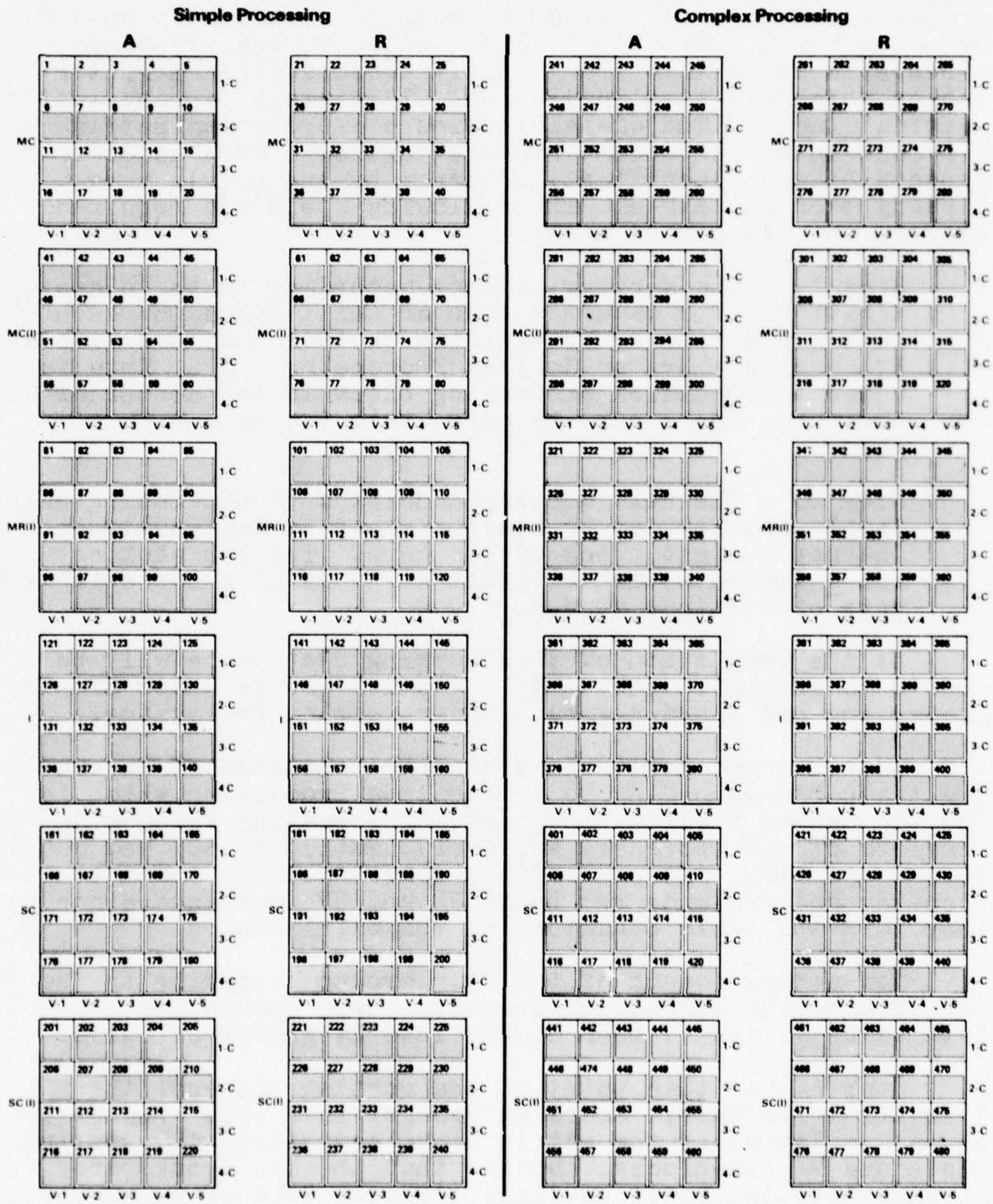


Figure 19. Classification matrix board.

Each sub-block is labeled at the left according to the six Information Processing choices described in Step 3. Each sub-block is also labeled at the right and bottom of the block. The 1-C, 2-C, 3-C, and 4-C labeling at the right sorts out the Cues Quantity block of the skill card. The V-1, V-2, V-3, V-4, and V-5 labeling of each block sorts the Motor Action Output Index. These two sortings should be done together. If care has been taken to group all skill cards properly, this sorting to the matrix board will be a simple matter.

Researchers on this project started with sub-blocks containing sorting slots 1 through 20. This sub-block visually sorts out all data as Simple Processing or SP, Establish Aircraft Attitude or A, and Multi-Cue Processing or MC. Take this group of cards and note the Quantity and Output Index data. For example, if the data on the card read 3-C and V-2, the card would fall into slot number 12. All card data are sorted to the matrix board in the same way. Researchers then went to the next sub-block containing sorting slots 21 through 40 and repeated the process with the next batch of cards, until all cards had been sorted into sub-block sorting slots.

Step 5. - Now that all the skill cards have been separated into their proper sorting slots according to the first five hierarchy levels, one final breakdown remains. This is done for each sorting slot containing skill cards. The simplest method to accomplish this is to remove the cards from each slot and sort them according to Cues Kind, Input Index, Input/Output Index, and Control Output. This can be done by laying out the cards on a table and sorting them into groups according to these data. Skill cards having identical data should be clipped together. An ordering within individual groups may be made according to task number. All cards are then returned to the slot. It should be noted that even though the sorting is done within the sorting slot, not all skill cards will fall in identical groups. The single cards within a sorting slot form a second level of one-of-a-kind skills.

Step 6. - When all skill cards have been sorted within each slot, each card must be numbered according to the sorting slot into which it has been placed within the hierarchy. This slot number is placed in the upper right-hand corner of each card.

Step 7. - With the numbering complete, it is then possible to make up a sorting slot list. This may be done according to the format shown in Appendix B.

Step 8. - With the taxonomic data system complete, the final step is to recheck the system for clerical errors. If care has been taken during the sorting process, these errors will be few. Experience has shown that each step during the structuring of a taxonomy must be checked for errors.

It is not until the data are applied that all errors present themselves. Even during this working stage, errors have not been difficult to rectify. The basic system has been found sufficiently simple and flexible to make necessary changes.

With a completed data system, the training developer is ready to apply the taxonomy in a variety of ways. The application phase is described in Volume III of this report. In Volume III the taxonomist is given a series of examples which elaborate various uses of the data system in addressing real-world tactical flying training problems.

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GLOSSARY

Anticipate - the mental activity which occurs prior to a particular portion or segment of a task and triggers the decision process for a number of subsequent task sequences.

Aural - cues or stimuli which can be sensed through hearing.

Basic Skill - the significant pattern of activity contained within a single cues, mental action or motor action sequence of the surface analysis.

Classification Hierarchy - the ranking of the adopted classification rules in successive order according to the number of sorting variables contained in each rule, graduating from the fewest choices to the largest number of choices.

Classification Instructions - the concise set of regulations which determined the application of each classification rule to information described in each task sequence within the surface analysis.

Classification Matrix Board - the board upon which the taxonomic hierarchical system of basic divisions, sub-blocks and sorting slot divisions was developed for the orderly categorization of classified skill information.

Classification Rules - the set of nine guidelines adopted in this study which were used to establish the behavioral element categories for the cues, mental action and motor action components of the surface task analysis.

Control - a device used by a pilot in operating an airplane.

Control Feedback - cues or stimuli which can be sensed by body limbs or extremities through the control devices of the aircraft. The control feedback input has been shortened to <u>Control</u> in the cues column of the surface analysis.

Coordinate - the movement or use of two or more controls in their proper relationship to obtain a desired effect.

Coordinated Outputs - those control actions which were performed simultaneously in the motor action description of the surface task analysis.

Cue - environmental or system stimuli which excite the sensory systems of the human body.

Data Notation Card - the notation form designed to hold the coded behavioral information of an individual task sequence as determined by the behavioral element categories within the classification rules. The card is also called a skill card in the text because of the coded basic skill information it contains.

Determine - the mental activity which occurs in the problem solving and decision making processes.

Discerns - the mental activity which occurs with the recognition of a specific cue.

Effector Output - pilot motor action in terms of control exerted on the aircraft, i.e., stabilator movement resulting from control stick movement to change aircraft pitch attitude.

Long Term Memory - information which was acquired prior to the performance of the skill.

Maneuver - any planned motion of the aircraft in the air or on the ground.

Matrix Sub-Block - that portion of the classification matrix made up of 20 sorting slots which specifically categorized all skills with respect to cue kind, cue complexity, and motor action complexity rules, and provided the framework for the further isolation of skills into basic skill groups.

Memory Recall Processing - the mental action involving the recollection of procedures or facts about the performance of a task prior to performing it.

Mental Action - cognitive process initiated by perceived stimulus cues and preceding motor actions.

Motion - cues or stimuli which can be sensed by the body receptors as a result of aircraft movement.

Motor Action - those physical actions resulting in movement of aircraft controls.

Sequential Outputs - the control actions which are performed in uninterrupted succession to one another.

Short Term Memory - information remembered which was obtained during the performance of a skill.

Skill - all the behavioral activity required for the accomplishment of a specific task in real time within the tolerances of prescribed criteria.

Sorting Slot - the grouping area within the classification matrix sub-block which categorizes skill data with respect to motor output, input index and input/output index rules.

Specific Cue Processing - the mental action dealing with the perception and recognition of a specific cue and related to the use of short term memory storage.

Surface Task Analysis - a systematic description of an interaction between surface elements (i.e., cue, motor action, and the depth element, mental action) as they relate to the environment, the criteria, and the system.

Sustain - the mental activity which maintains a task segment in which the cue parameters remain constant.

Task - a group of related work elements performed in close temporal proximity by one person and directed toward the accomplishment of a definable goal.

Task Element - the smallest part of the surface analysis which is expressed as a major input or action heading, i.e., cues or mental actions or motor actions are task elements of the analysis.

Task Sequence - a complete set of interacting behavioral elements (i.e., cues, mental action and motor action) found in the surface task analysis.

Taxonomy - a manner of classifying, and the rules and principles concerned with classification of phenomena in such a way that a more useful relationship can be established among them.

Visual - cues or stimuli which can be sensed by the eye.

APPENDIX A

MENTAL ACTION CATEGORIES

Mental Actions - The mental action category involved four separate mental processes which were basic to the performance of most hand, foot, and eye tasks. Discerns, sustains, anticipates, and determines were selected as behavioral verbs to describe the mental actions for this analysis. Each behavioral verb is listed below with its respective cognitive description. These descriptions are specifically oriented to flying situations as they pertain to the surface task analysis.

Use of the Mental Action Categories

Behavior	Information Processing	Cognitive Description
Discerns	Specific Cue Processing (Short Term Memory Process/ Storage)	This behavior occurs with the perception and recognition of a specific cue. This process utilizes short term memory storage. The identification of a desired airspeed, the observation of a specific point at which a task sequence is to begin, or the comprehension of a verbal communication are examples of the activities which require that cues perceived be remembered only long enough to recognize the correlation with an actual situation and a desired state.
Sustains	Continuous Iterative Processing (Short Term Memory Process)	This behavior occurs as cyclic short term memory processing which maintains a task segment in which cue parameters remain constant (wired). It is the mental activity required to control an aircraft during a turn, after the roll in and before the roll out. Similar mental activity may occur during climbs, descents, and cruise flight.

Behavior	Information Processing	Cognitive Description
Anticipates	Memory Recall Processing (Long Term Memory Process/ Storage)	This behavior occurs prior to a particular portion of a task and triggers the decision process for a number of subsequent task sequences. It is the precursor of subsequent mental actions and involves the recalling of learned facts and routines required for the planning of tasks. Anticipation involves long term memory storage of procedures or facts about the performance of the task.
Determines	Multi-Cue Processing (Short Term & Long Term Memory Process)	This behavior occurs in the basic decision making and problem solving processes and always involves multiple cues and evaluations. This is the most elaborate and complex mental activity. Determination also identifies the decision making and problem solving processes which ascertain the extent to which a motor action should be done or has been done.

APPENDIX B

COMPLETE SORTING SLOT LIST

SORTING SLOT CONTENTS LIST

Slots 1 thru 20			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	1-11 None	17	CR-7g(K)/ CR-7a(O),
12	/CR-3g(AAA), CR-4g(MM)/		CR-2g(OO), CR-6g(MM)/
	CR-2g(CC), CR-5g(R),		CR-1g(II), CR-7g(JJ)/
	CR-3g(AAA)		CR-1g(NN), CR-2g(X),
	13-14 None		CR-3g(V), CR-3g(NN),
15	/CR-3g(ZZ), CR-7g(NN)/		CR-5g(F)
	CR-6g(LL)		18-19 None
16	/CR-1a(K), CR-3g(CC)/	20	/CR-1a(E), CR-1a(S)/
	CR-1a(L), CR-6a(P)		CR-1a(W), CR-3g(Q),
17	/CR-1g(K), CR-2g(K),		CR-6g(F)
	CR-4g(K), CR-6g(K),		

Slots 21 thru 40			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	21-29 None	35	None
30	CR-1g(Q)	36	CR-1g(HH), CR-7g(II)
31	/CR-1g(FF), CR-4g(FF)/	37	CR-1a(EE), CR-3a(H),
32	CR-4g(L), CR-6g(FF),		CR-4a(Q), CR-2g(HH)
	CR-7g(L)	38	None
33	None	39	None
34	None	40	CR-2a(O)

SORTING SLOT CONTENTS LIST

Slots 121 thru 140			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	121-131 None		133-136 None
132	CR-1a(O), CR-1a(T),	137	/CR-4g(T), CR-6g(S)/
	CR-4a(A), CR-2g(AA),		CR-6a(Q), CR-8a(R)
	CR-3g(G)		138-140 None

Slots 141 thru 160			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	141-156 None		158-160 None
157	CR 1a(BB), CR-4a(I)		

Slots 161 thru 180			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	161-176 None		178-180 None
177	CR-3a(R)		

Slots 181 thru 200			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	181-191 None	195	CR-5g(Y)
192	CR-5g(C)	196	CR-1a(J)
	193-194 None		197-199 None
195	CR-1a(C), CR-2a(D),	200	/CR-1a(U), CR-7a(D)/ CR-3g(T)

SORTING SLOT CONTENTS LIST

Slots 41 thru 60			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	41-46 None	52	CR-9a(C)
47	CR-3g(A)		53-60 None
	48-51 None		

Slots 61 thru 80			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	61-76 None		78-80 None
77	CR-1g(V)		

Slots 81 thru 100			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	81-86 None	92	CR-9a(I), CR-6g(II),
87	CR-9a(B)		CR-5g(B), CR-7g(KK)
	88-91 None		93-100 None

Slots 101 thru 120			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	None		

SORTING SLOT CONTENTS LIST

Slots 201 thru 220			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	201-206 None	217	CR-1a(M), CR-8a(L),
207	CR-5g(A), CR-5g(T)		CR-8a(P), CR-3g(Y),
	208-211 None		CR-3g(DD), CR-3g(EE),
212	CR-1a(A), CR-1a(N),		CR-5g(AA), CR-5g(EE)
	CR-5g(X)		218-220 None
	213-216 None		

Slots 221 thru 240			
Slot	Basic Skill Groups		
	None		

Slots 241 thru 260			
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	241-246 None		248-250 None
247	/CR-1g(B), CR-4g(B)/	251	CR-5g(E)
	CR-3g(B)		
252	/CR-1g(DD), CR-2g(DD), CR-7g(BB), CR-7g(EE)/		
	CR-1g(N), CR-2g(N), CR-4g(N), CR-5g(V)/		
	CR-1g(CC), CR-6g(AA), CR-7g(DD)/		
	CR-1g(EE), CR-7g(FF)/ CR-3g(L), CR-7g(N)/		
	CR-3a(Q), CR-4a(D) Cont'd on next page		

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups
252	CR-5a(B), CR-2g(BB), CR-3g(QQ), CR-3g(RR), CR-6g(N)
	253-254 None
255	/CR-1g(LL), CR-1g(MM), CR-5g(DD)/
	CR-2g(NN), CR-4g(LL)/ CR-1a(I)
256	/CR-8a(Q), CR-2g(M), CR-4g(M), CR-6g(M)/
	CR-7a(F), CR-6g(HH)/ CR-3g(VV), CR-7g(M)/
	CR-1g(M), CR-6a(O)
257	/CR-3a(I), CR-3a(N), CR-3g(K)/
	CR-3a(P), CR-3g(JJ), CR-6g(W)/
	CR-4a(M), CR-4a(N)/ CR-1g(Z), CR-7g(Z)/
	CR-2g(Y), CR-4g(X)/ CR-4a(F), CR-4a(L), CR-5a(Q),
	CR-8a(F), CR-8a(J), CR-9a(H), CR-1g(AA), CR-3g(X),
	CR-3g(OO), CR-4g(Y), CR-4g(BB), CR-5g(K), CR-6g(X),
	CR-6g(BB), CR-7g(AA)
258	None
259	CR-5a(P)
260	/CR-1g(S), CR-3g(F), CR-4g(S), CR-6g(R)/
	CR-5a(E), CR-6a(I), CR-7g(S)/
	CR-5a(J), CR-9a(G), CR-2g(F)/
	CR-1g(F), CR-7g(F)/
	CR-8a(E), CR-8a(O), CR-9a(Q), CR-4g(F)

SORTING SLOT CONTENTS LIST

	Slots 261 thru 280
Slot	Basic Skill Groups
	261-266 None
267	CR-5a(H)
268	None
269	CR-3g(O), CR-4g(D), CR-7g(R)
270	/CR-4g(Q), CR-6g(P)/ CR-1a(Q), CR-1a(Y), CR-1g(KK),
	CR-2g(D), CR-2g(P), CR-3g(D), CR-5g(M), CR-7g(D),
	CR-7g(Q)
271	CR-3g(TT), CR-7g(GG)
272	/CR-1g(L), CR-6g(L)/ CR-2g(L), CR-5g(U)/
	CR-4g(AA), CR-6g(Z)/ CR-1a(H), CR-5a(R), CR-1g(T),
	CR-2g(FF), CR-7g(T)
273	None
274	CR-7g(MM)
275	/CR-1g(I), CR-2g(I), CR-3g(XX), CR-3g(YY),
	CR-4g(I), CR-4g(JJ), CR-4g(KK), CR-6g(I)/
	CR-1g(J), CR-2g(J), CR-4g(E), CR-4g(J),
	CR-6g(J), CR-7g(J)/ CR-1a(AA), CR-1a(CC), CR-3g(J),
	CR-5g(P), CR-7g(LL)/ CR-2g(MM), CR-6g(KK), CR-7g(I)/
	CR-3g(I), CR-5g(Q)/ CR-4a(B), CR-7a(B), CR-9a(D),
	CR-9a(J), CR-9a(N), CR-3g(P), CR-2g(LL), CR-1g(D),
	CR-6g(D), CR-6g(JJ) Cont'd on next page

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups
276	/CR-7a(K), CR-8a(S), CR-9a(L)/
	/CR-3g(BB), CR-3g(KK), CR-5g(I)/
	/CR-4g(HH), CR-5g(J)/ CR-2g(II), CR-5g(D)/ CR-5a(M)
277	/CR-1a(D), CR-3a(L), CR-3a(M), CR-7a(Q), CR-3g(MM)/
	CR-1a(Z), CR-3a(K), CR-3g(II)/
	CR-2g(JJ), CR-3g(UU), CR-4g(GG)/ CR-2a(F), CR-2a(G)/
	CR-3a(G), CR-8a(N)/ CR-1a(DD), CR-2a(V), CR-4a(C),
	CR-4a(R), CR-5a(I), CR-6a(C), CR-7a(I), CR-7a(J),
	CR-7a(R), CR-8a(D), CR-9a(F), CR-9a(K), CR-9a(S),
	CR-9a(T), CR-9a(U), CR-9a(V), CR-9a(W), CR-9a(X),
	CR-9a(Z), CR-1g(GG), CR-2g(GG), CR-3g(AA), CR-6g(GG),
	CR-7g(HH)
278	None
279	/CR-7a(E), CR-2a(I), CR-2a(K), CR-1g(X), CR-7g(X),
	CR-7g(Y)/ CR-9a(O), CR-1g(R), CR-2g(Q)/ CR-7a(L)
280	/CR-2a(U), CR-3a(J), CR-5a(C), CR-5a(G), CR-5a(L),
	CR-5a(N), CR-7a(H), CR-2g(S), CR-4g(R), CR-5g(O),
	CR-4g(V), CR-6g(Q), CR-6g(U)/ CR-2a(M), CR-4a(G),
	CR-5a(D), CR-5a(H), CR-8a(H), CR-2g(R), CR-4g(W)/
	CR-5a(O), CR-6a(N), CR-7a(M), CR-9a(AA),
	CR-3g(HH), CR-5g(CC)/ CR-4a(H), CR-6a(H),
	CR-6a(M), CR-8a(I)/ CR-1a(R), CR-2g(V), CR-3g(U)/

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups
280	/CR-2a(J), CR-2a(L), CR-2a(W)/ CR-1a(V), CR-4a(P)/
	CR-3a(F), CR-3g(W)/ CR-6a(G), CR-3g(LL)/
	CR-6a(L), CR-8a(M)/ CR-1g(Y), CR-6g(E)/
	CR-2g(E), CR-7g(E)/ CR-2g(W), CR-6g(V)/
	CR-3g(E), CR-5g(N)/ CR-3g(GG), CR-5g(BB)/
	CR-2a(H), CR-2a(W), CR-3a(B), CR-3a(C), CR-7a(C),
	CR-7a(N), CR-9a(E), CR-9a(Y), CR-1g(E), CR-5g(Z)
	Slots 281 thru 300
Slot	Basic Skill Groups
	281-286 None
287	/CR-1g(A), CR-2g(B), CR-4g(A), CR-6g(B),
	CR-7g(A), CR-7g(B)/ CR-9a(A), CR-1g(O), CR-7g(O)/
	CR-2g(A), CR-6g(A)/
	CR-8a(A), CR-3g(M), CR-4g(O), CR-5g(S)
	288-291 None
292	/CR-2g(G), CR-6g(G)/ CR-4g(DD), CR-4g(EE)/ CR-2a(A),
	CR-2a(C), CR-3a(O), CR-6a(A), CR-3g(SS), CR-4g(G),
	CR-4g(CC), CR-6g(DD), CR-6g(EE)
	293-296 None
297	/CR-3a(A), CR-6a(F)/ CR-4a(E), CR-6a(K)/
	Cont'd on next page

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups
297	/CR-3a(D), CR-6a(J)/ CR-2a(P), CR-2a(R), CR-2a(S),
	CR-2a(T), CR-4a(J), CR-9a(R), CR-6g(CC)
	298-300 None

Slots 301 thru 320	
Slot	Basic Skill Groups
	301-316 None
317	CR-1a(FF), CR-7a(U), CR-7g(V)
	318-320 None

Slots 321 thru 340	
Slot	Basic Skill Groups
	321-326 None
327	/CR-1g(P), CR-2g(C), CR-4g(C), CR-6g(C), CR-6g(O)/
	CR-8a(B), CR-2g(O), CR-3g(N)/ CR-5g(A), CR-7a(A)/
	CR-5g(L), CR-7g(P)/ CR-5g(G)
	328-331 None
332	/CR-1a(B), CR-1g(BB), CR-5g(W), CR-6g(Y)/
	CR-2g(Z), CR-3g(PP), CR-7g(C)/ CR-1g(H), CR-7g(H)/
	CR-2g(KK), CR-3g(H)/ CR-4g(P), CR-7g(CC)/
	CR-1a(P), CR-2a(B), CR-1g(C), CR-1g(JJ), CR-2g(EE), CR-3g(C), CR-3g(WW)
	Cont'd on next page

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups	Slot	Basic Skill Groups
	333-336 None	337	CR-2g(H), CR-4g(H),
337	/CR-5a(F), CR-7a(G),		CR-6g(H)/
	CR-9a(M), CR-4g(U)/		CR-8a(K), CR-2g(U)/
	CR-4a(O), CR-3g(FF),		CR-1a(X), CR-2a(Q),
	CR-3g(Z), CR-4g(II)/		CR-3a(E), CR-6a(B),
	CR-5a(K), CR-1g(W),		CR-4g(Z)
	CR-3g(S), CR-6g(T)/		338-340 None

	Slots 341 thru 360		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	341-356 None		358-360 None
357	/CR-9a(P), CR-7g(W)/		

	Slots 361 thru 380		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	361-371 None	372	CR-2g(T), CR-3g(R)
372	/CR-1g(G), CR-7g(G)/		373-380 None

	Slots 381 thru 400		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	381-391 None		393-396 None
392	CR-1a(F), CR-7a(P)		Cont'd on next page

SORTING SLOT CONTENTS LIST

Slot	Basic Skill Groups	Slot	Basic Skill Groups
397	CR-1g(U)		398-400 None

	Slots 401 thru 420		
Slot	Basic Skill Groups		
	None		

	Slots 421 thru 440		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	421-434 None	440	CR-1a(G), CR-2a(E),
435	CR-8a(C)		CR-4a(K)
	436-439 None		

	Slots 441 thru 460		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	441-456 None	457	CR-8a(G)
457	CR-6a(D), CR-6a(E),		458-460 None

	Slots 461 thru 480		
Slot	Basic Skill Groups	Slot	Basic Skill Groups
	461-476 None		478-480 None
477	CR-7a(S)		

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